Mapping methane emissions from the three gorges reservoir area: A feasibility study

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Abstract:
The concern about the emissions of methane from flooded lands as a result of constructing huge dam has been expressed while no scientific study on the total amount and spatial distribution of CH_4 emissions over the three gorges reservoir area is carried out yet. The feasibility of utilizing remote sensing (RS) data for mapping CH_4 emissions from the three gorges reservoir area, China, is explored. Though direct derivation of methane emissions from satellite data is not reliable, there are a few successful examples using empirical models based on field measurements. By means of a RS approach, maps representing environmental variables relevant to methane emissions can be derived and then are combined to map and predict the methane emissions over the three gorges reservoir area. Soil moisture, soil temperature, slope, aspect, vegetation biomass and water depth are considered as key parameters targeted in this study. The result of this study shows the viability of remote sensing as a means of mapping and predicting methane emissions from inundated lands.

Key words: methane emissions, remote sensing, three gorges area, spatial distribution

Introduction

The three gorges dam (China) is under construction and will be finished in 2009. This ongoing dam project has been attracting worldwide attention. It will be the largest hydroelectric dam in the world. Both positive and negative effects exist. Generation of hydro-electricity will reduce the pressure from lack of power for the rapidly developing country; seasonally flooded downstream of Yangtze River will be under better control. However, issues like displacement of almost two million people, rapid silting up of reservoir, destroy of history cultural sites and rare biotic species received disputation.

As a large area to be flooded with the river closure work going on, methane will be generated by microorganisms living in the oxygen-poor environments. The three gorges dam is thought to be significant source of atmospheric methane and consequently emitted methane, as an important greenhouse gas, will affect the climate.

Surprisingly, no scientific study on the total amount and spatial distribution of methane emissions over the three gorges reservoir area is carried out yet. Only very recently, the concern about the emissions of methane from flooded lands as a result of constructing huge dam has been expressed [4].

Some research indicates that dams and their associated reservoirs are globally significant sources of emissions of the greenhouse gases, carbon dioxide and, in particular, methane. Vincent St. Louis estimated that reservoirs of all types and sizes worldwide release 70 million tons of methane annually, which equals about one-fifth of the estimated methane emissions from all other human activities [4].

Thus, carrying out a research aiming to map the methane emissions from the three gorges reservoir area would be of significance. The major benefits from the research results to the society and the major scientific significance include:

1. Develop innovative methods to predict the spatial distribution of methane emissions over large reservoir area which is under construction;
2. Give a scientific answer on the amount of methane emissions caused by this controversial hydroelectric project;
3. Provide the Chinese government with necessary information for management of the project to reduce the emissions of green house gas;
4. Provide with scientific data for the study on China's climate change or even global climate change.

This paper will explore the feasibility of utilizing remote sensing (RS) data for mapping CH_4 emissions from the three gorges reservoir area. It will start with an overview of a few methane emissions mapping projects, which were already carried out, followed by a background introduction on three gorges dam project and its flooded area. Next will be a discussion on the feasibility of a proposed research approach, comprising four steps. Finally it will end up with a conclusion.

An overview of methane emissions mapping projects

The concern on the global warming made the study on the measurement of methane emissions a hot research field. Researches have been carried out over many areas that are major sources of CH_4. Among those, paddy fields have been widely and frequently studied globally [2,13,14,15]. Some researchers showed interests in the emissions from wetlands [8,10]. There is only limited study on the swine houses [11] and landfills [7]. One study was on the Arctic tundra by using a remote sensing approach to map the methane emissions [12]. There is no study over reservoir areas and flooded areas except that Prsenqvist, et al (1998) estimated methane emissions from the Jau river floodplain in Brazil [9].

Generally two approaches were taken in these studies. Field measurement based approach was most frequently applied. Static chambers were often used to collect methane in sample areas and then followed by measuring the sample gas using gas chromatography. The total emissions over the study area will be a product of direct measurement and areas of same type of fields. It can provide accurate results in a homogeneous area. Wang et al (1994) designed continuous measurement system for methane emissions from paddy field for prediction and this system could reduce uncertainty in the estimation of CH_4 [14]. While studying on a large scale where the area is heterogeneous, indirect approach was introduced. Empirical models were often developed to relate CH_4 emissions to affecting factors [2,13,15]. Soil properties, such as soil temperature, soil moisture, and other environmental variables were found that there are strong relationship between them and CH_4 emissions. When studying over a large area, remote sensing becomes an interesting approach. Balloon-mounted/ airplane-mounted laser spectrometry was used to directly measure methane emissions [3]; satellite images were also used in some studies in a regional scale [15], but in an indirect way. For instance, Yan M.,et al (2000) tried satellite data to derive the areal extent of study area to calculate the total emissions over Changchun area.

Study area

The three gorges reservoir area includes all the flooded area caused by the three gorges dam. It extends along Yangtze River, covering an area from Yichang city in Hubei Province to Chongqing area (E106^{o}14' – 111^{o}28', N25^{o}56' – 31^{o}44'). (See Figure one for an overview of the three gorges dam reservoir area)

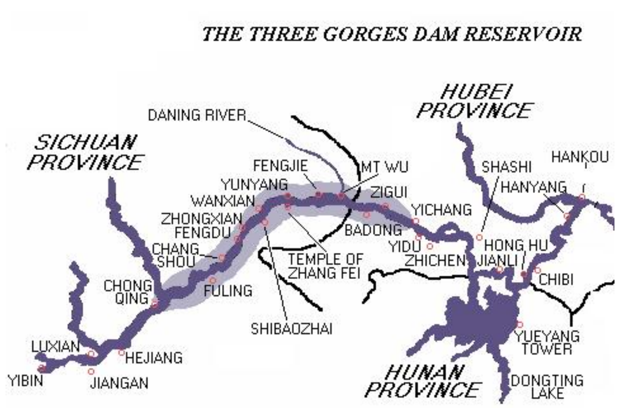

Figure one: The three gorges dam reservoir. Yangtze River is in dark blue. The reservoir area is in light blue.

The area has complicated landform, with difference in altitude from 1000m to 1500m. The area has a mild climate. In extreme weather in winter, temperatures there are not less than 5 degrees below zero centigrade, while the yearly average temperature is above 15 degrees centigrade. In addition, the area's humidity can be kept at around 80 percent. Besides, the area has plentiful precipitation.

The three gorges dam project consists of three stages starting in 1993 and finishing in 2009. The water level in the reservoir area will be increased step by step: Firstly, it was increased to 10-75m after the closure work on November 8^{th}, 1997; Secondly, to 135m in June 2003; Thirdly, to 156m in 2006 and finally 175m till the accomplishment in 2009. When the normal water level of 175 m is achieved, the reservoir will cover more than 1,000 sq.km and stretch some 663km. The Three Gorges Reservoir will inundate more than 600 sq. km., the world's largest inundated area by a single project. Thus, methane emissions will be increased over this area.

Proposed methodology

Due to the big area (around 600-km long) and complicated topographical characteristics, remote sensing would be a very suitable tool to map the methane emissions from the three gorges reservoir area. Noticing the fact that emissions levels vary widely among reservoirs depending upon such factors as the area and type of ecosystems flooded, reservoir depth and shape, the local climate, the way in which the dam is operated and the ecological, physical and socio-economic characteristics of the dammed river basin, a spatial model is more suitable to present this variability [1].

As Ashcroft and Morel (1995) discussed, directly derive methane emissions from satellite is still not reliable. Thus, developing an indirect approach using environmental variables derived from satellite data and empirical model based on field measurements is a feasible solution, comprising the followed four steps.

Step one: Delineate the study area

The study area includes the area that will be flooded in 2009. To delineate the study area, digital elevation model (DEM) and land cover map could be used. They both exist over the study area. And, radar data and TM/ASTER images could be used to improve the classification accuracy for the purpose of identifying the sources and sinks of methane, especially the classification of wetlands in this area.

Step two: Develop methane emissions model based on field measurements

Field measurements will be based on different land cover types. For non-inundated area, soil moisture, soil temperature, slope, aspect and vegetation biomass can be measured; for inundated area, water depth and aboveground vegetation biomass can be measured. The methane emissions can be measured by gas chromatography with the use of static chamber.

Based on the field measurement of potential affecting environmental variables, different multivariate analysis can be applied to derive methane emissions model for different land cover types for this area.

Step three: Map Vegetation biomass, soil moisture, soil temperature, slope, aspect and water depth

To spatially extrapolate methane emissions values for the study area, maps representing environmental variables relevant to methane emissions according to the above-mentioned model could be derived from satellite data and DEM:

Vegetation biomass map can be derived from NDVI image using an empirical relationship between field measurements of NDVI and image NDVI. The results from Li and Dong (1996) indicated that microwave remote sensing would be great potential for monitoring soil moisture [6]. Soil moisture map can be derived from Radar SAR data using an empirical relationship between SAR signal (after geometric and radiometric corrections) and soil moisture measured in the field. Soil temperature map can be calculated by many approaches [5], among which is using the relationship between soil temperature field measurements and net solar radiation derived from DEM. Slope and aspect can be derived directly from DEM. Water depth of water body and wetlands could be derived using both existing hydrological data and DEM.

Step four: Map methane emissions

The maps of affecting environmental variables will then be combined by using the empirical methane emissions model to map and predict the methane emissions over the three gorges reservoir area.

Conclusions

For such a huge anthropic activity, three gorges dam project deserves long-term concern on its impact on environment. Mapping methane emissions over the area is possible. By means of a remote sensing approach, maps representing environmental variables relevant to methane emissions can be derived and then are combined to map and predict the methane emissions over the three gorges reservoir area. Soil moisture, soil temperature, slope, aspect, vegetation biomass and water depth are considered as affecting parameters in mapping methane emissions. The result of this study shows the viability of remote sensing as an indirect means of mapping and predicting methane emissions from inundated lands. This made possible that mapping the distribution (sources/sinks) of methane emissions of current year and 2009; mapping the changes of methane emissions caused by the ongoing dam project and calculate the sum of methane emissions to present the impact of three gorges dam on methane emissions and furthermore, long-term impact on climate. A small final comment is that as the reliability of the result heavily depends on empirical models based on field sampling, the dynamics of emissions rate deserves further study to find the representative sampling time.

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